CLOUDBURST AT TULSA, OKLAHOMA, JULY 27, 1963

STAFF, River Forecast Center, U.S. Weather Bureau, Tulsa, Okla.
and
District Meteorological Office, U.S. Weather Bureau, Kansas City, Mo.

ABSTRACT

On July 27, 1963, a storm produced rainfall intensities that exceeded prior records for Tulsa, Okla. The location of a portion of this storm over an urban area permitted the collection of an unusual amount of rainfall data for the size of the area. Depth-area-duration relationships based on recording-gage data are presented. A meteorological analysis of the storm indicates low-level convective activity with nearly calm high-level winds resulted in the almost stationary thunderstorm situation responsible for the excessive rainfall rates.

1. INTRODUCTION

The storm of July 27, 1963, over the City of Tulsa, Okla. and adjacent metropolitan areas exceeded all previous records of rainfall intensities for durations of 5 min. to 24 hr. at Tulsa. The recording-gage data indicate that the storm rainfall began between 0800 and 0900 CST over the northern limits of the isohyetal pattern and ended at about 1400 CST over the southern portion (figs. 1 and 2). The records also indicate that the duration of the intense rainfalls was approximately 3 hr.

Although meteorological radars showed that, in general, the thunderstorms over north-central Oklahoma had easterly trajectories throughout the storm period, the cells responsible for the Tulsa area rainfalls appear to have developed and moved or intensified southwestward along the direction of the major axis of the isohyetal pattern. Public Service Power Company officials reported an unusually high frequency of cloud-to-earth lightning strikes during this storm. However, there were no reports of hail or unusual winds.

2. UNOFFICIAL RAINFALL DATA

The total-storm isohyetal map (fig. 1) was developed primarily from the data obtained by an appeal to the public and from field "bucket surveys" made by the staff members of the Tulsa River Forecast Center. All Tulsa news media cooperated in the appeal to the public for their information, and the two Tulsa newspapers carried a printed form for individual use, in addition to the story on the potential value of a proposed rainfall study. Slightly over 200 rainfall reports were received through mail and telephone replies from individuals within a 200-mi.^{2} area who had specific information on the rainfall at their residences. A large percentage of the 200 unofficial reports were based upon observations from commercial-type rain gages of limited capacity. These reports were screened and generally found acceptable for rainfall values of less than 5 in. total. Several instances were uncovered where individuals had anticipated rain gage overflow and had emptied their gages at least once during the storm period.

In the subsequent field survey, the staff discovered a large number of "unreported" gages, suggesting the existence of unsuspected unofficial high-density "networks" for obtaining supplemental rainfall information in urban areas. The data for point rainfalls in excess of 5 in. were, for the most part, obtained from the field surveys of the volumes of rainfall caught in receptacles of various sizes and shapes, converted to true catch. The isohyets in the vicinity of the City Water Supply Reservoir (fig. 1) are based upon a 14.4-in. catch in the reservoir. This 434-acre reservoir is of water-tight construction, and accurate data were available on its catch dimensions, changes in reservoir elevation, and controlled inflows and outflows during the storm duration, for the computation of a 14.4-in. rainfall catch. A vertical concrete wall surrounds the reservoir and there is no inflow from surrounding land areas.

3. RECORDING-GAGE DATA

Rainfall records were available (fig. 2) from 6 recording gages and one semi-official, visual-type gage at the River Forecast Center (RFC). In addition to the official Weather Bureau recording gage located at the Airport, the City of Tulsa had just recently installed five recording gages of 12-in. capacity throughout the City. These latter gages were subsequently calibrated and found to be accurate within ± 0.07 in. throughout the range of their respective catches. The true clock times of these latter records could not, however, be ascertained with the accuracy desired for development of isochronal patterns to depict the areal development or progression of the intense centers of rainfall. From discussions with the regular City rain gage tender, it was estimated that the probable range in synchronization error would be no more than ± 15 min.

Clock-hour increments of rainfall for each of the six recording gages and the RFC gage are listed in table 1.

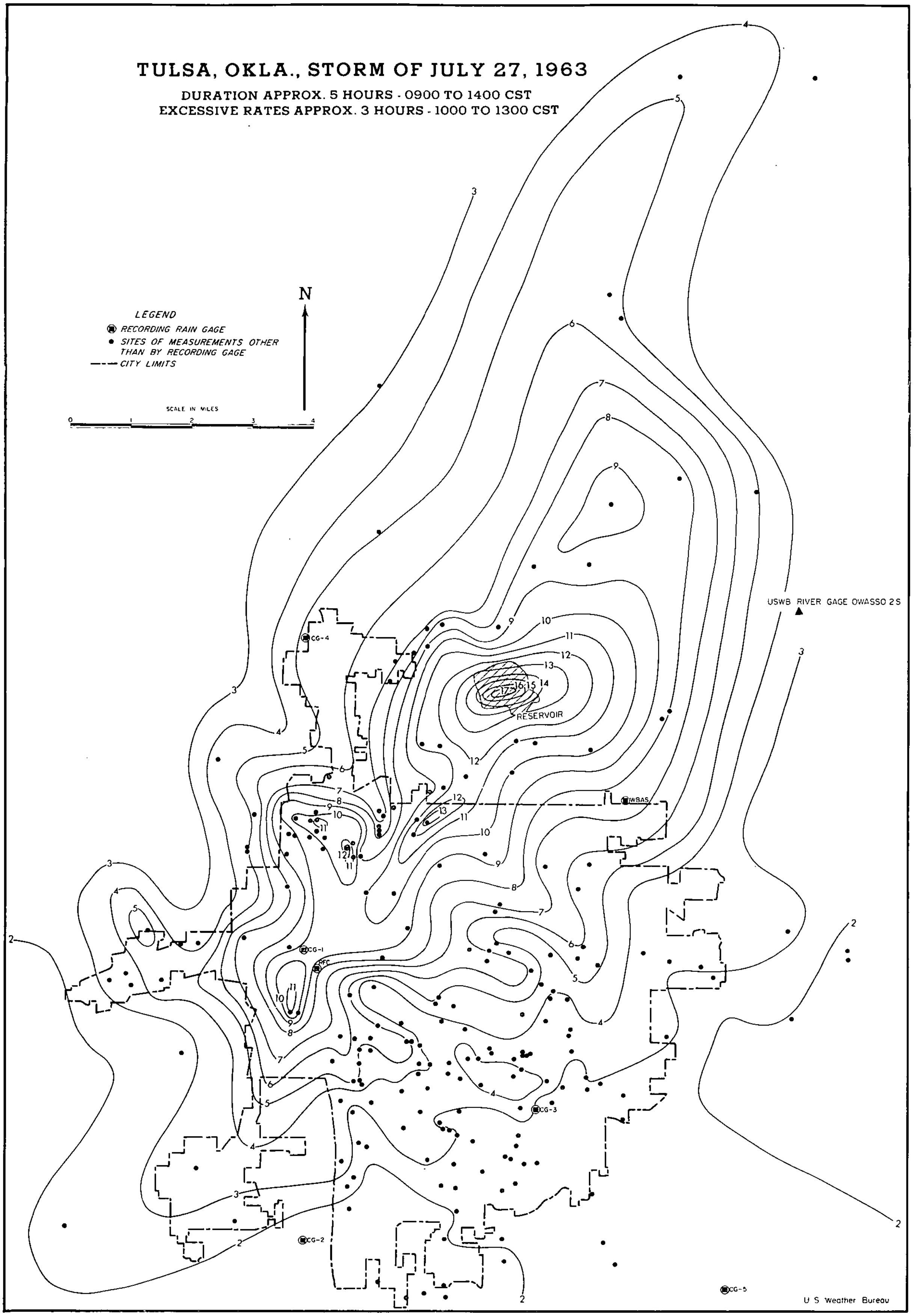

FIGURE 1.—Total-storm isohyetal map for the July 27, 1963, storm at Tulsa, Okla. Isohyets labeled in inches.

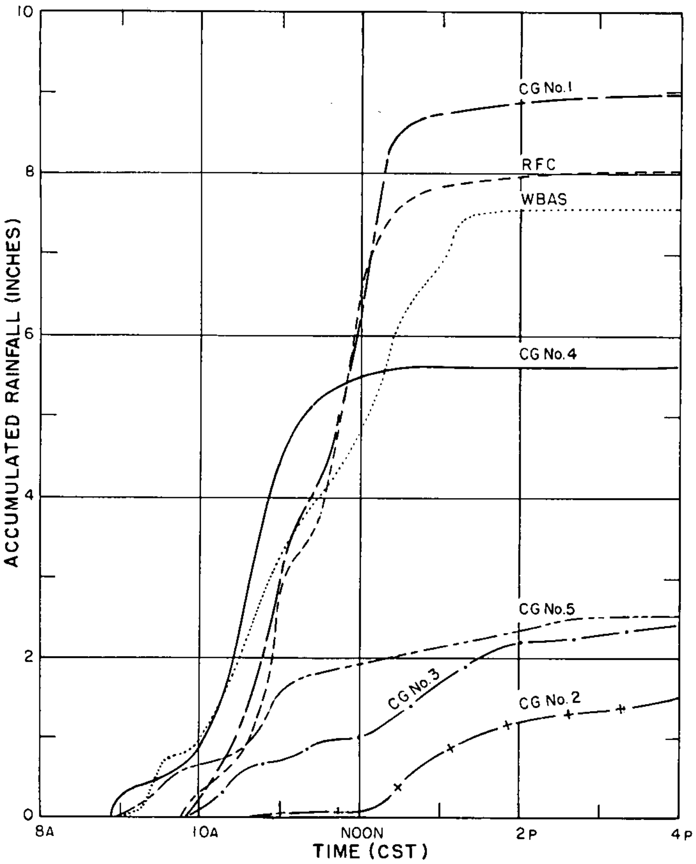

FIGURE 2.—Mass rainfall curves for the six recording gages and the RFC visual gage.

The official Weather Bureau gage at the Airport location received less rainfall than either City gage No. 1 or the RFC gage. Excessive rates for durations from 10 to 180 min. at the WBAS gage and City gages Nos. 1 and 4 are listed in table 2.

TABLE 1.—*Rainfall amounts (inches) for hourly intervals ending at the indicated times* (CST) *at recording gage stations.*

Station	Time (CST)								Storm total
	0900	1000	1100	1200	1300	1400	1500	1600	
WBAS	T	0.95	2.32	1.53	2.08	0.63	0.03	T	7.54
CG-1	0	0.22	2.73	3.05	2.72	0.16	0.08	0.02	8.98
CG-2	0	0	0.04	0.01	0.73	0.40	0.18	0.13	1.49
CG-3	0	0.10	0.58	0.33	0.66	0.53	0.10	0.10	2.40
CG-4	0.30	0.65	3.50	1.03	0.12	0.01	0.01	0.01	5.63
CG-5	0	0.65	0.95	0.33	0.24	0.17	0.16	0	2.50
RFC	0	0.30	2.55	3.50	1.50	0.09	0.11	0	8.05

TABLE 2.—*Observed excessive rainfall rates (rainfall in inches)*

Station	Duration (minutes)									
	10	20	30	45	60	80	100	120	150	180
WBAS	0.90	1.30	1.60	2.00	2.47	2.90	3.40	4.00	5.50	5.97
CG No. 1	1.65	------	2.90	------	4.15	------	------	7.45	------	8.70
CG No. 4	0.75	------	1.75	------	3.55	------	------	4.75	------	5.40

732-570—64——2

TABLE 3.—*Comparison of maximum rainfall intensities measured by City gage No. 1 with 100-yr. values* [1]

Duration	Rainfall amounts (in.)	
	Gage No. 1	100-Year
10 minutes	1.65	1.8
30 minutes	2.90	3.2
60 minutes	4.15	4.1
2 hours	7.45	4.9
3 hours	8.70	5.4
6 hours	8.98	6.4
12 hours	8.98	7.6
24 hours	8.98	8.9

TABLE 4.—*Maximum average depth of rainfall (inches)*

Area (sq. mi.)	Duration (hours)					
	1	2	3	4	5	6
1	5.1	8.0	11.6	13.4	14.0	14.1
2	4.9	7.8	11.1	12.8	13.4	13.5
5	4.6	7.4	10.3	11.8	12.5	12.6
10	4.3	7.0	9.6	11.0	11.7	11.8
20	3.9	6.5	8.8	10.0	10.6	10.7
50	3.3	5.5	7.3	8.1	8.6	8.7
100	2.9	4.5	5.6	6.3	6.7	6.8

4. RECORD RAINFALL RATES

The July 27 storm produced new official rainfall records at Tulsa Airport for durations from 100 min. through 24 hr. Maximum rainfall rates measured at the Airport station were exceeded by those at City gage No. 1 for all durations through 24 hr. and by those at City gage No. 4 for durations from 30 to 120 min. (table 2). The intensities measured at City gage No. 1 are the maximum ever observed in Tulsa for all durations through 24 hr. It is reasonable to assume that the intensities associated with the major rainfall centers greatly exceeded those measured by the recording gages.

A comparison of the intensities observed at City gage No. 1 with the corresponding 100-yr. values projected for the Tulsa area in [1] is presented in table 3. The fact that amounts for durations up to 60 min. were less than or about equal to the corresponding 100-yr. values while the 2-, 3- and 6-hr. amounts were about $1^1/_2$ times the 100-yr. values suggests that the record values produced by the July 27 storm resulted primarily from a nearly stationary severe storm situation rather than from thunderstorm activity of unparalleled intensity.

A conventional depth-area-duration analysis [2] of the storm rainfall was made to determine the maximum rates for various durations over various sizes of area up to 100 mi.², which is just slightly less than the area enclosed by the large 4-in. total-storm isohyet (fig. 1). The analysis was made for hourly intervals since uncertainty as to synchronization of the six recording gages made the use of shorter intervals unwarranted. The results of the analysis are presented in table 4.

While the maximum average depths shown in table 4 are of unusual magnitude they are nowhere near the maxima for northeastern Oklahoma, which seems to be

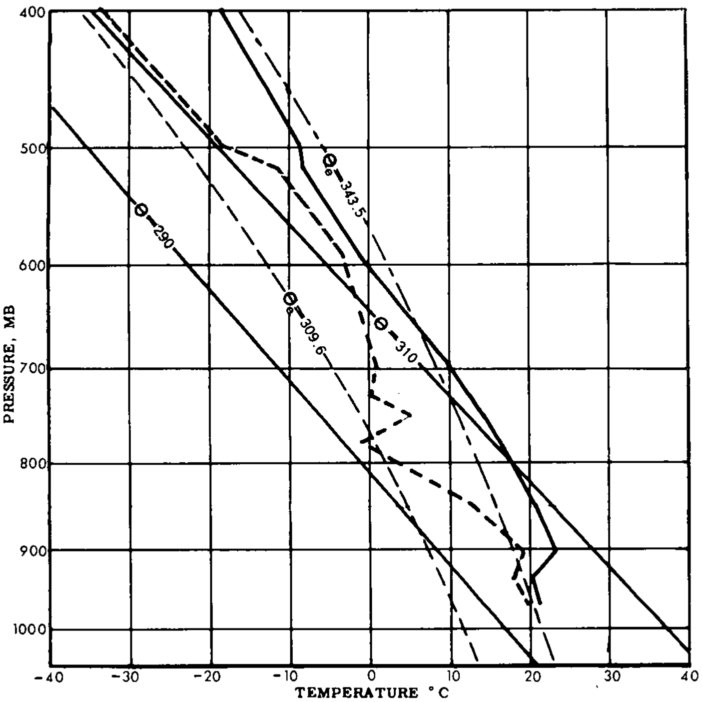

FIGURE 3.—Radiosonde observation for Oklahoma City, 0600 CST, July 27, 1963.

TABLE 5.—*Comparison of maximum 6-hr. rainfalls (inches) in four outstanding storms in northeastern Oklahoma*

Location of storm center	Date	Area (square miles)	
		10	100
Hallett	Sept. 4, 1940	18.4	14.7
Warner	May 9, 1943	9.9	8.7
Mounds	May 16–17, 1943	15.9	14.2
Tulsa	July 27, 1963	11.8	6.8

a region favored by outstanding storms. Table 5 presents a comparison of the 6-hr. amounts of the July 27 storm with those of three other outstanding storms [3] for that region. These three storms, all centered within a radius of 60 mi. from Tulsa, are: (1) the Hallett storm [4] of September 2–6, 1940, (2) the Warner storm of May 6–12, 1943, and (3) the Mounds storm of May 12–20, 1943. Most unusual is the fact that greatest rainfall intensities in the Warner and Mounds storms occurred within a week of each other. Incidentally, it was the Warner storm that gave Tulsa the previous 24-hr. record value of 7.30 in. (May 9–10, 1943) exceeded by the July 27, 1963, storm (7.54 in.).

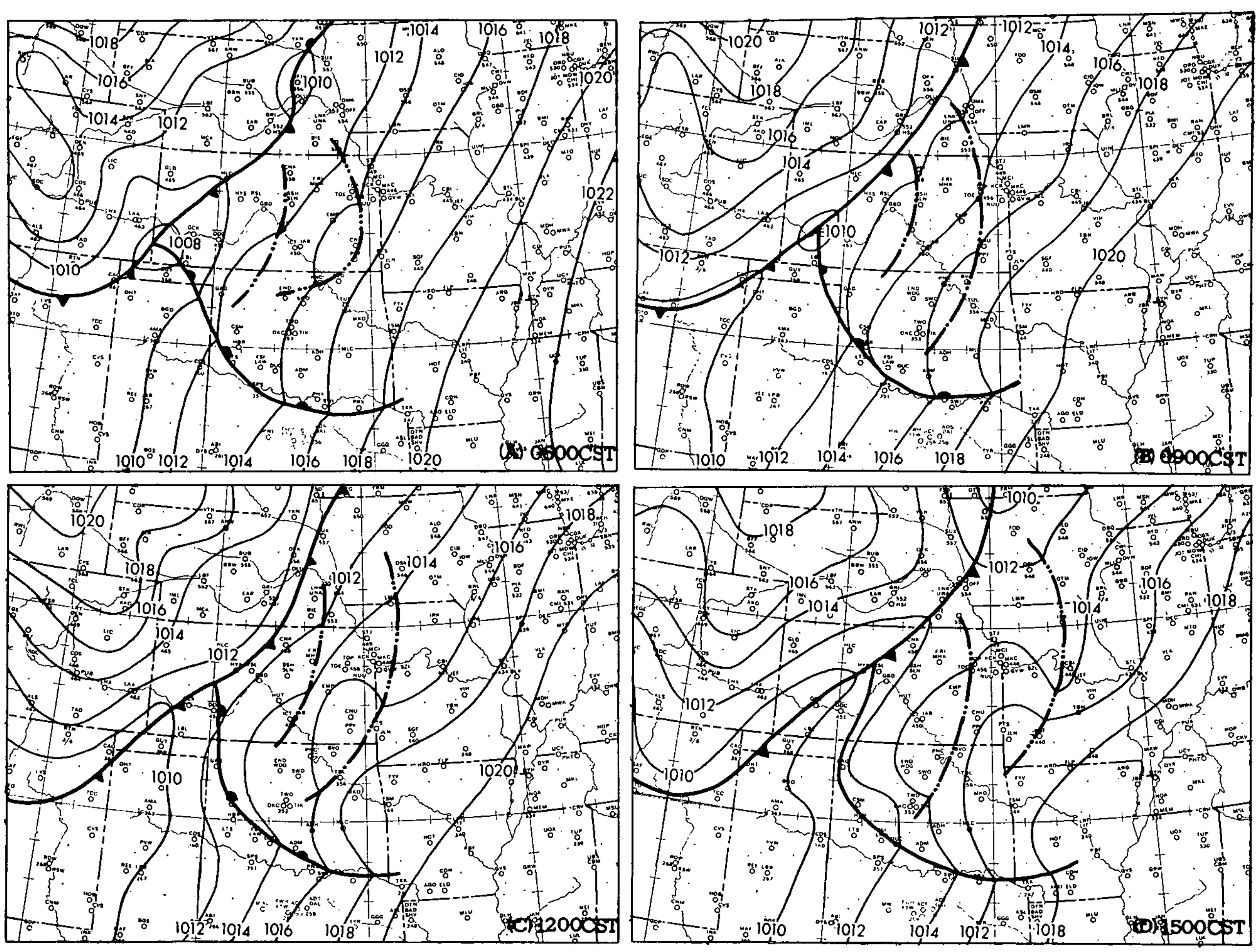

FIGURE 4.—Synoptic surface maps for July 27, 1963.

5. RUNOFF INVESTIGATIONS

A preliminary investigation was made to determine whether the storm pattern of figure 1 was hydrologically reasonable. Surface runoff was computed for the areas using the standard rainfall-intensity-runoff relationships developed by the RFC and distributed by the standard 12-hr. effective-precipitation technique to forecast the flow hydrograph at the Owasso 2S river gage on Bird Creek (fig. 1). A continuous stage hydrograph for Owasso 2S was not available since observations were limited to a few occasional readings of the wire-weight gage. However, close approximations of volume and crest height were obtained. A more detailed study involving the application of river-forecasting techniques to the solution of runoff volumes and distributions from such areas is being made for subsequent presentation.

6. METEOROLOGICAL ANALYSIS

The July 27, 1963, storm was a local, or small-scale, phenomenon. The meteorological network was not adequate to permit a detailed analysis of such a localized event, but a study of the data does give an insight into conditions associated with the event.

At 0600 CST on the 27th, conditionally unstable air with high moisture content lay over the area south and west of Tulsa. The 0600 CST radiosonde observation for Oklahoma City (fig. 3) is typical of the air mass flowing into northeastern Oklahoma. Surface dew points in the air mass were 65° to 75° F., and the water content in the lower 3000 ft. averaged 14 to 15 gm./kg. The lifted indices at 0600 CST were determined to be: Fort Worth −6.5; Fort Sill, −6.0; Amarillo, −6.0; and Oklahoma City, −8.0. (The lifted index [5] is defined as the temperature difference between the observed 500-mb. temperature and the assumed 500-mb. temperature of a mean parcel of air lifted from the 3000-ft. layer next to the ground. Indices are negative for parcel temperatures that are warmer than the environmental temperature.)

There were several indications that the moist air would be lifted over northeastern Oklahoma during the day.

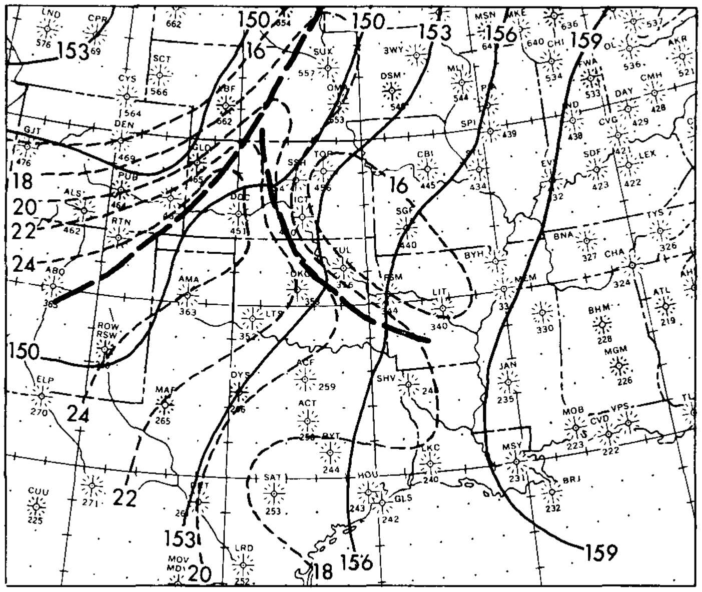

FIGURE 5.—850-mb. chart for 0600 CST, July 27, 1963. Height are in tens of meters; isotherms (dashed lines), in °C.

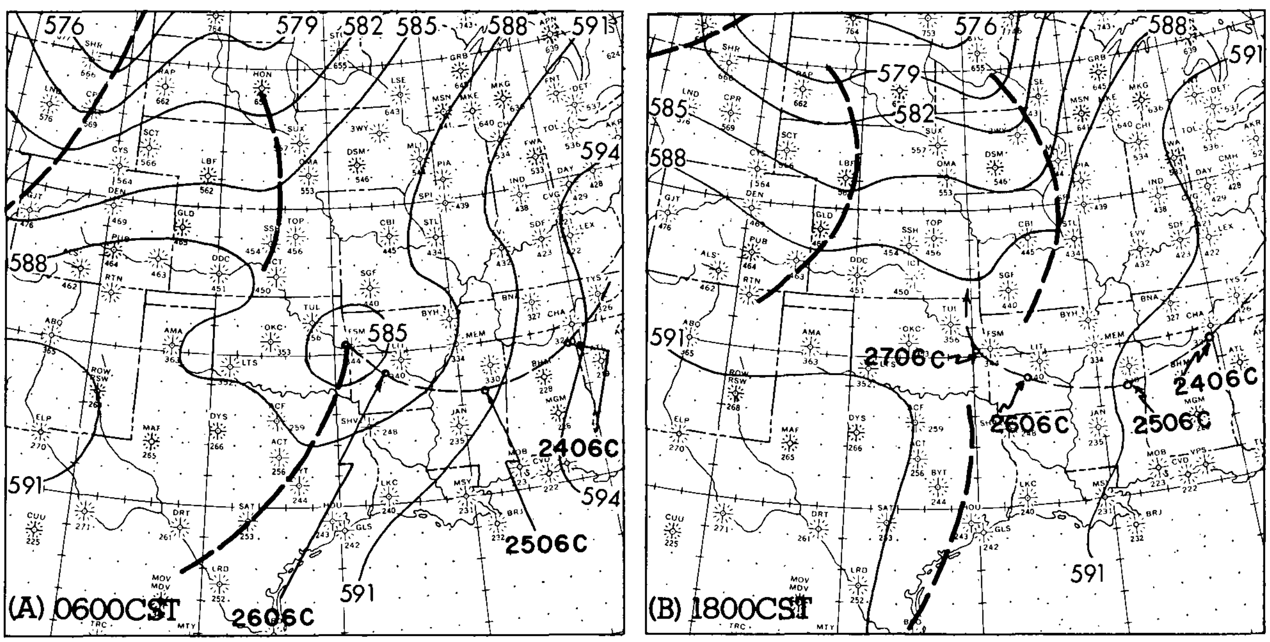

FIGURE 6.—500-mb. charts for July 27, 1963, showing track (light dashed line) of Low center for previous 3 days and positions at 24-hr. intervals. Heights are in tens of meters.

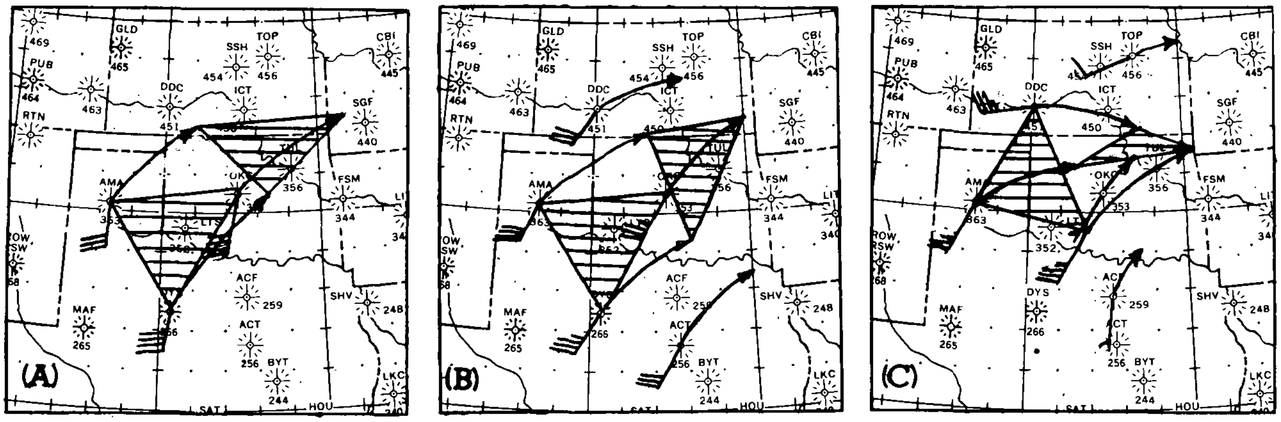

FIGURE 7.—Six-hour dynamic trajectories computed from 0600 CST data for period 0600–1200 CST, July 27, 1963. (A) Computed from surface geostrophic winds and observed 4000-ft. wind. (B) Computed from 850-mb. geostrophic and observed winds. (C) Computed from 700-mb. geostrophic and observed winds.

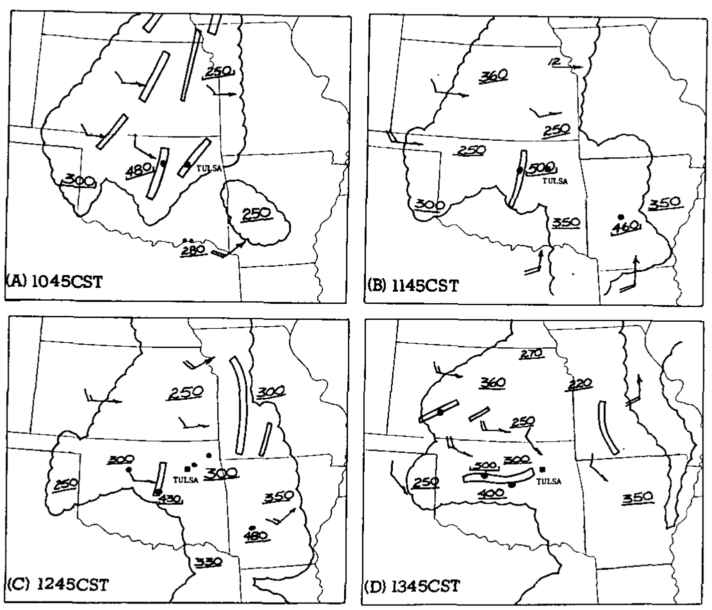

FIGURE 8.—Radar echoes on July 27, 1963. Solid lines outline the areas of radar echoes. The rectangles are bands or lines of showers or thunderstorms. The arrows show the direction and speed of movement of these areas and lines, one full barb indicating 10 kt. The dots are locations of convective cells of extreme activity whose tops are given in hundreds of feet.

The surface synoptic charts (fig. 4) show the approach of a trough and cold front from the Central Plains moving southeastward toward a strong low-level flow of southerly winds. On these and other charts Tulsa is identified as TUL. The 850-mb. chart for 0600 CST (fig. 5), indicates isentropic upslope from Oklahoma City (OKC), where the temperature was 22° C., to the northeastern portion of the State (16° C.). On the 0600 CST 500-mb. chart (fig. 6A) a Low was located in the northeastern Oklahoma area. This Low migrated from the east and was attended by precipitation amounts of 1 to 2 in. The Low center passed over or just to the east of Tulsa during the period of precipitation thereby reducing stability in that vicinity.

Six-hour trajectories (fig. 7) were made for the period from 0600 to 1200 CST. The trajectories are the paths of particular air parcels as determined by the observed and geostrophic winds (cf. [6]). Contraction of an original area represents horizontal convergence. Computations made for gradient level, the 850-mb. level, and the 700-mb. level show convergence. The strongest convergence was at the 700-mb. level where the original area was diminished to approximately one-third. These processes were favorable for heavy rain, but are not an adequate explanation for the excessive amounts observed.

The plot of radar echoes (fig. 8) shows that the thunderstorm cells remained in about the same position in the Tulsa area for the 3-hr. period 1045 through 1345 CST. Also, analyses of the surface data (fig. 4) show that the southern end of the instability line remained in the area for several hours.

The Low, that had existed at 500 mb. for the past three days, opened into a trough and split after 0600 CST (fig. 6), with one part moving northward into eastern Kansas and western Missouri, while the other part moved southward into eastern Texas. This breakup of the Low was attended by a drop in wind speed to almost calm at high levels over northeastern Oklahoma. These high-level winds probably backed from northeast to calm and finally to an accelerating west wind during the period of heavy rain. While the low-level winds were contributing to convective activity, the lack of high-level winds favored a nearly stationary thunderstorm condition, resulting in excessive precipitation. In time, the increasing west winds scattered the cells and distributed the rainfall over a wider area.

CREDITS

The section on the storm statistics, i.e., isohyetal pattern, mass curves, comparative data, etc., was prepared by the staff of the Tulsa River Forecast Center under the direction of Mr. P. R. Jones,

Hydrologist in Charge. The meteorological analysis was made by the staff of the District Meteorological Office at Kansas City, Mo., under the direction of Mr. D. C. House, Meteorologist in Charge.

REFERENCES

1. U.S. Weather Bureau, "Rainfall Frequency Atlas of the United States for Durations from 30 Minutes to 24 Hours and Return Periods from 1 to 100 Years," *Technical Paper* No. 40, May 1961 (reprinted 1963) 61 pp.
2. U.S. Weather Bureau, "Manual for Depth-Area-Duration Analysis of Storm Precipitation," *Cooperative Studies Technical Paper* No. 1, September 1946 (reprinted March 1949) 73 pp.
3. Corps of Engineers, U.S. Army, "Storm Rainfall in the United States," 1945.
4. G. A. Lott, "An Extraordinary Rainfall Centered at Hallett, Okla.," *Monthly Weather Review*, vol. 81, No. 1, Jan. 1953, pp. 1–10.
5. U.S. Weather Bureau, "Forecasting Tornadoes and Severe Thunderstorms," *Forecasting Guide* No. 1, September 1963, p. 15.
6. U. S. Weather Bureau, "On Quantitative Precipitation Forecasting," *National Hurricane Research Project Report* No. 38, August 1960, pp. 3–4.

[*Received February 24, 1964*]